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# **The Effect of Small-Scale Ocean Fluctuations on Ocean Acoustic Transmission**

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## **LONG-TERM GOALS**

To connect the results of sound transmission and scattering experiments to known or hypothesized structures within the hydrosphere, such as internal waves or microstructure, with account taken of ocean anisotropy, inhomogeneity, and the sound channel.

## **OBJECTIVES**

To study the effects of time evolution of internal waves; to compare different techniques for the calculation of acoustic fluctuations at ranges of 1000 km and larger.; to study the effects of three-dimensional internal-wave structure on acoustic fluctuation behavior; to form a global picture of the effect of internal waves on sound. To summarize decades of work on the path-integral theory in one paper containing all the results.

## **APPROACH**

We have chosen, with graduate student Mike Vera, to simulate realizations of oceans filled with internal waves, and to calculate acoustic fluctuations by use of the paraxial approximation, and three calculational techniques: geometrical optics (ray integration), multifrequency parabolic-equation solving, and numerical integration based on formulae derived from the path-integral technique. With graduate student James Gerber, we have moved toward three-dimensional effects by simulating propagation through a homogeneous, isotropic environment. For his thesis work, Gerber calculated the intensity coherence function with geophysical time. In forming a global picture of internal-wave effects, Masters student Kimberly Noble used the Levitus data base.

## **WORK COMPLETED**

An article by Noble and Flatte' in JASA described the strength of acoustic effects as a function of geographical position and season. An article by Flatte' and Rovner provided the summary of decades of work on the path-integral technique. An article by Gerber and Flatte' described calculations of the intensity coherence function of time. An article by Flatte' and Gerber in J. Opt. Soc. Am. A took Simulation of optical propagation through 3D turbulence to the highest values of turbulence strength ever attained in simulations. An article by Flatte' and Vera is in review at JASA describing the effect of internal-wave time evolution on acoustic fluctuations.

## **RESULTS**

We have shown that the effect of internal waves on acoustic propagation is proportional to a quantity labelled “F” whose value varies by factors of 5 over different parts of the world ocean. We have shown that internal-wave time evolution has a substantial effect on acoustic fluctuations; the “frozen” hypothesis is not valid. We have shown that the results of the path-integral formulas for travel-time wander and spread are not in quantitative agreement with simulations using the parabolic equation at ranges of more than 1000 km. We have shown that even at turbulence strengths that are 300 times the value when weak-fluctuation theory breaks down, asymptotic theory is still not accurate.

## **IMPACT/APPLICATIONS**

Our map of internal-wave effect on acoustics (F) could be used to decide on locations of future experiments, as well as future naval operations. Internal-wave time evolution must be considered in predicting the behavior of acoustic fluctuations. Many of our results can be summarized by saying that theories of various kinds are not quantitative compared with full simulations; the implication is that simulations will have to be done in the design and operation of ocean acoustic systems rather than using simple equations.

## **TRANSITIONS**

None

## **RELATED PROJECTS**

None

## **PUBLICATIONS**

Stanley M. Flatte’ and Michael D. Vera: The effect of internal-wave time dependence on chaotic ocean acoustic rays, submitted to JASA October 2000.

James S. Gerber and Stanley M. Flatte’: The intensity coherence function of time for partially saturated acoustic propagation through ocean internal waves, J. Acoust. Soc. Am. 109:528-537, February 2001

Stanley M. Flatte’ and James S. Gerber: Irradiance variance behavior for plane- and spherical-wave optical propagation through strong turbulence, J. Opt. Soc. Am. A, 17:1092--1097, June 2000.

Stanley M. Flatte’ and Galina Rovner: Calculations of internal-wave-induced fluctuations in ocean-acoustic propagation, J. Acoust. Soc. Am. 108:526-534, August 2000.

Kimberly J. Noble and Stanley M. Flatte’: Predicting acoustic fluctuations due to internal waves from the basic climatology of the world ocean, J. Acoust. Soc. Am. 107:747-757, February 2000.